DESIGN AND FABRICATION OF ABRASIVE JET MACHINE

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology

In

Mechanical Engineering

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Rourkela

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2009

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CERTIFICATE

This is to certify that the thesis entitled "**DESIGN AND FABRICATION OF ABRASIVE JET MACHINE**" Submitted by MR. KRUSHNA PRASAD PRADHAN in partial fulfillment of the requirements for the award of Bachelor of technology Degree in Mechanical Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

DATE:

Dr. C. K. BISWAS

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May 11, 2009

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CONTENTS

ABSTRACT

Abrasive Jet Machining (AJM) is the process of material removal from a workpiece by the application of a high speed stream of abrasive particles carried in a gas medium from a nozzle. The material removal process is mainly by erosion. The AJM will chiefly be used to cut shapes in hard and brittle materials like glass, ceramics etc. the machine will be automated to have 3 axes travel. The different components of AJM are Horizontal motion module (X-Y Table), Vertical motion module (Z- motion), Vibrator, dehumidifier, Pressure Regulator, and Dust filter etc. The different components are selected after appropriate design calculations.

In this project, a model of the Abrasive Jet Machine is designed using CAD packages like AutoCAD, CATIA etc taking into consideration of commercially available components. Care has been taken to use less fabricated components rather than directly procuring them, because, the lack of accuracy in fabricated components would lead to a diminished performance of the machine.

PART ONE

INTRODUCTION

1.1 Introduction

Abrasive Jet Machining (AJM) is the removal of material from a workpiece by the application of a high speed stream of abrasive particles carried in gas medium from a nozzle. The AJM process differs from conventional sand blasting in that the abrasive is much finer and the process parameters and cutting action are carefully controlled.

The process is used chiefly to cut intricate shapes in hard and brittle materials which are sensitive to heat and have a tendency to chip easily. The process is also used for deburring and cleaning operations. AJM is inherently free from chatter and vibration problems. The cutting action is cool because the carrier gas serves as a coolant.

1.2 Equipment

A schematic layout of AJM is shown in Fig-1. The filtered gas, supplied under pressure to the mixing chamber containing the abrasive powder and vibrating at 50 c/s, entrains the abrasive particle and is the passed into a connecting hose. This abrasive and gas mixture emerges from a small nozzle at high velocity. The abrasive powder feed rate is controlled by the amplitude of vibration of the mixing chamber. A pressure regulator controls the gas flow and pressure.

The nozzle is mounted on a fixture. Either the workpiece or the nozzle is moved by cams pantograph or other suitable mechanisms to control the size and shape of the cut. Hand operation is sometimes adequate to remove surface contaminations or in cutting where accuracy is not very critical. Dust removal equipment is necessary to protect the environment. Commercial bench mounted units including all controls, motion producing devices, and dust control equipment are available.

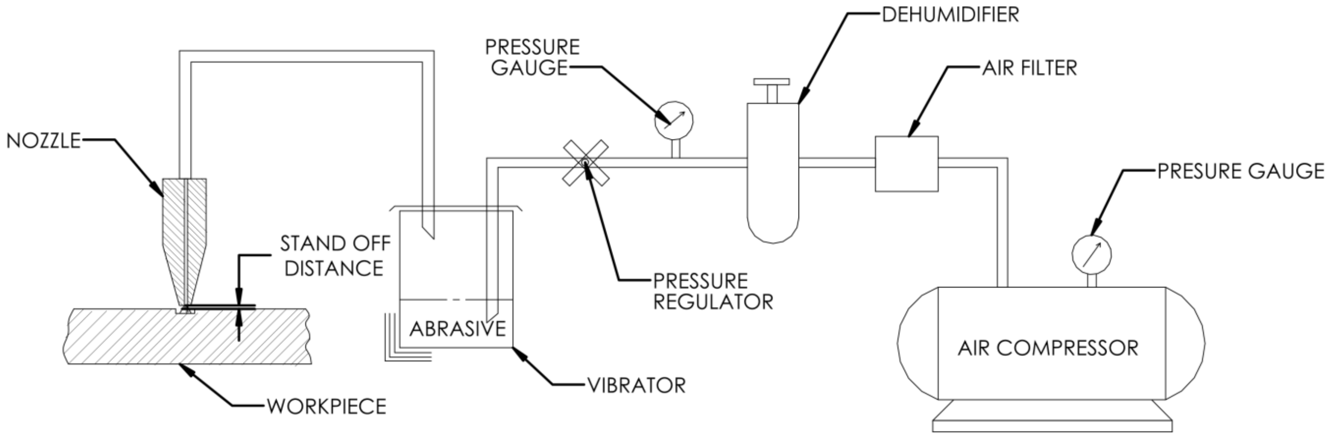

FIG-1: SCHEMATIC LAYOUT OF ABRASIVE JET MACHINE

The major components are:

1. Air compressor.
2. Air filter.
3. Dehumidifier.
4. Pressure Gauge.
5. Pressure Regulator.
6. Vibrator or Mixer.
7. Nozzle.
8. Horizontal and Vertical motion module (for xyz motion).
9. Arrangement to hold the workpiece.

1.3 Variables in Abrasive Jet Machine:

The variables that influence the rate of metal removal and accuracy of machining in this process is:

1. Carrier gas
2. Types of abrasive
3. Size of abrasive grain
4. Velocity of abrasive jet
5. Flow rate of abrasive
6. Work material
7. Geometry, composition and material of nozzle
8. Nozzle work distance (stand off distance)
9. Shape of cut and operation type

1.3.1 Characteristics of different Variables:

Medium	Air , CO_2 ,N_2
Abrasive	SiC, Al_2O_3 (of size 20µ to 50µ)
Flow rate of abrasive	3 to 20 gram/min
Velocity	150 to 300 m/min
Pressure	2 to 8 kg/cm2
Nozzle size	0.07 to 0.40 mm
Material of nozzle	WC, Sapphire
Nozzle life	12 to 300 hr

Stand off distance	0.25 to 15 mm (8mm generally)
Work material	Non Metals like glass, ceramics, and granites. Metals and alloys of hard materials like germanium, silicon etc
part application	Drilling, cutting, deburring, cleaning

TABLE-1

1.4 Advantages:

1. Ability to cut intricate holes shape in materials of any hardness and brittleness.
2. Ability to cut fragile and heat sensitive material without damage.
3. No change in microstructure as no heat is generated in the process.
4. Low capital cost.

1.5 Disadvantages:

1. Material removal rate is low and hence its application is limited.
2. Stray strings can occur and hence its application is limited.
3. Embedding of the abrasive in the workpiece surface may occur while machining softer material.
4. The abrasive material may accumulate at nozzle and fail the process if moisture is present in the air.
5. It cannot be used to drill blind holes.

1.6 Application:

The major field of application of AJM process is in the machining of essentially brittle materials and heat sensitive materials like glass, quartz, sapphire, semiconductor materials, mica and ceramics. It is also used in cutting slot, thin sections, countering, drilling, deburring, for producing integrate shapes in hard and brittle materials. It is often used for cleaning and polishing of plastics nylon and Teflon components. Delicate cleaning, such as removal of smudges from antique documents, is also possible with AJM.

PART TWO

LITERATURE SURVEY

2.1 Literature survey:

The literature study of Abrasive Jet Machine reveals that the Machining process was started a few decades ago. Till date there has been a through and detailed experiment and theoretical study on the process. Most of the studies argue over the hydrodynamic characteristics of abrasive jets, hence ascertaining the influence of all operational variables on the process effectiveness including abrasive type, size and concentration, impact speed and angle of impingement. Other papers found new problems concerning carrier gas typologies, nozzle shape, size and wear, jet velocity and pressure, stand-off-distance (SOD), or nozzle-tip-distance (NTD). These papers express the overall process performance in terms of material removal rate, geometrical tolerances and surface finishing of work pieces, as well as in terms of nozzle wear rate. Finally, there are several significant and important papers which focus on either leading process mechanisms in machining of both ductile and brittle materials, or on the development of systematic experimental-statistical approaches and artificial neural networks to predict the relationship between the settings of operational variables and the machining rate and accuracy in surface finishing.

[Ref-17] Computational fluid dynamics (CFD) simulation of the formation and discharge process of an air-water flow in an abrasive waterjet (AWJ) head is presented by Umberto Prisco & Maria Carmina D'Onofrio. Numerical simulations have been conducted using the commercial code Fluent® 6.3 by Ansys. Dynamic characteristics of the flow inside the AWJ head and downstream from the nozzle has been simulated under steady state, turbulent, two-phase flow conditions. The final aim is to gain fundamental knowledge of the ultrahigh velocity flow dynamic features that could affect the quality of the jet, such as the velocity and pressure distributions in different parts of the AWJ head and at the outlet.

[Ref-20] Experiments have been performed on effect of jet pressure, abrasive flow rate and work feed rate on smoothness of the surface produced by abrasive water jet machining of carbide of grade P25. Carbide of grade P25 is very hard and cannot be machined by conventional techniques. The abrasive used in investigations was garnet of mesh size 80. It was tried to cut carbide with low and medium level of abrasive flow rate, but the jet failed to cut carbide since it is too hard and very high level of energy is required. Minimum rate of abrasive flow that made it possible to cut carbide efficiently was 135 g min^{-1}. With increase in jet pressure the surface becomes smoother due to higher kinetic energy of the abrasives. But the surface near the jet entrance is smoother and the surface gradually becomes rougher downwards and is the roughest near the jet exit. Increase in abrasive flow rate also makes the surface smoother which is due to the availability of higher number of cutting edges per unit area per unit time. Feed rate didn't show significant influence on the machined surface, but it was found that the surface roughness increases drastically near the jet entrance.

The study of the results of machining under various conditions approves that a commercial AJM machine was used, with nozzles of diameter ranging from 0.45 to 0.65 mm, the nozzle materials being either tungsten carbide or sapphire, both of which have high tool lives. Silicon carbide and aluminum oxide were the two abrasives used. Other parameters studied were nozzle tip distances (5–10 mm), spray angles (60° and 90°) and pressures (5 and 7 bars) for materials like glass, ceramics, and electro-discharge machined (EDM) die steel. The holes drilled by AJM may not be circular and cylindrical but almost elliptical and bell mouthed. High material removal rate conditions do not necessarily yield small narrow clean-cut machined areas.

(Ref-16) Studies reveal that AJM is an attractive micro-machining method for ceramic materials. The machinability during the AJM process can be compared to that given by the established models of solid particle erosion, in which the material removal is assumed to originate in the ideal crack formation system. However, it was clarified that the erosion models are not necessarily applicable to the AJM test results, because the relative hardness of the abrasive against the target material, which is not taken into account in the models, is critical in the micro-machining process. No strength degradation took place for the AJM ceramic surfaces. This is attributed to the fact that radial cracks did not propagate downwards by particle impacts during the machining process.

(Ref-14) Abrasive WaterJet (AWJ) turning is a technology that still tries to find its niche field of application where it can be economically viable. But a particular application of AWJ turning has proved its technological and economical capability, i.e. profiling and dressing of grinding wheels. Starting from the theoretical considerations, the key operating parameters of AWJ turning are identified and included in a methodology to generate various profiles of grinding wheels by means of tangential movement of the jet plume. Roughing in single pass to concave/convex geometries (experimented depth of cuts < 30 mm), generation of thin walls/slots (thickness < 2 mm, depth > 430 mm) and intricate profile (e.g. succession of tight radii) on a variety of grinding wheels show the capability of AWJ turning to fulfill the requirements of this niche application.

The machining process produces no heat and hence changes in microstructure or strength of the surface is unlikely. The air acts as a coolant and hence AJM process has a high potential as damage free micromachining method. The fracture toughness and hardness of the target materials are critical parameters affecting the material removal rate in AJM. However, their influence on the machinability varied greatly with the employed abrasives.

In recent years abrasive jet machining has been gaining increasing acceptability for deburring applications. The influence of abrasive jet deburring process parameters is not known clearly. AJM deburring has the advantage over manual deburring method that generates edge radius automatically. This increases the quality of the deburred components. The process of removal of burr and the generation of a convex edge were found to vary as a function of the parameters jet height and impingement angle, with a fixed SOD. The influence of other parameters, viz. nozzle pressure, mixing ratio and abrasive size are insignificant. The SOD was found to be the most influential factor on the size of the radius generated at the edges. The size of the edge radius generated was found to be limited to the burr root thickness.

[Ref-15] Abrasive jet finishing combined with grinding gives rise to a precision finishing process called the integration manufacturing technology, in which slurry of abrasive and liquid solvent is injected to grinding zone between grinding wheel and work surface under no radial feed condition. The abrasive particles are driven and energized by the rotating grinding wheel and liquid hydrodynamic pressure and increased slurry speed between grinding wheel and work surface achieves micro removal finishing.

Abrasive waterjet machines are becoming more widely used in mechanical machining. These machines offer great advantages in machining complex geometrical parts in almost any material. This ability to machine hard-to-machine materials, combined with advancements in both the hardware and software used in waterjet machining, has caused the technology to spread and become more widely used in industry. New developments in high pressure pumps provide more hydraulic power at the cutting head, significantly increasing the cutting performance of the machine. Analysis of the economic and technical has been done by researchers. Those technology advancements in applying higher power machining and intelligent software control have proven to significantly improve the overall performance of the abrasive waterjet machining operation, thus widening the scope of possible applications of this innovative and promising technology.

[Ref-21] Quality of the surface produced during abrasive water jet machining of aluminum has been investigated in recent years. The type of abrasive used was garnet of mesh size 80. The cutting variables were stand-off distance of the nozzle from the work surface, work feed rate and jet pressure. The evaluating criteria of the surface produced were width of cut, taper of the cut slot and work surface roughness. It was found that in order to minimize the width of cut; the nozzle should be placed close to the work surface. Increase in jet pressure results in widening of the cut slot both at the top and at exit of the jet from the work. However, the width of cut at the bottom (exit) was always found to be larger than that at the top (at a stand-off distance of 3 mm and the work feed rate of 15 mm min-1). It was found that the taper of cut gradually reduces with increase in stand-off distance and was close to zero at the stand-off distance of 4 mm (at a jet pressure of 30 ksi and a work feed rate of 15 mm min-1). The feed rate of the work should be kept within 40 mm min-1 (at the jet pressure of 30 ksi and the stand-off distance of 3 mm), because a feed rate beyond 40 mm min-1 results in sharp increase in taper angle. The jet pressure does not show significant influence on the taper angle within the range of work feed and the stand-off distance considered. Both stand-off distance and the work feed rate show strong influence on the roughness of the machined surface. Hence stand-off distance should be kept within 3 mm (at a jet pressure of 30 ksi and a work feed rate of 15 mm min-1) and the work feed rate should be kept within 30 mm min-1 (at a jet pressure of 30 ksi and a stand-off distance of 3 mm) in order to have a good surface finish, since beyond those values of the parameters the roughness of the machined surface rises sharply. Increase in jet pressure shows positive effect in terms of smoothness of the machined surface. With increase in jet pressure, the surface roughness decreases (at a stand-off distance of 3mm and work feed of 15 mm min-1). This is due to fragmentation of the abrasive particles into smaller sizes at a higher pressure and due to the fact that smaller particles produce smoother surface. So within the jet pressure considered, the work surface is smoother near the top surface and gradually it becomes rougher at higher depths.

Part Three

Design of Components

3.1 DESIGN OF COMPONENTS

3.1.1 X-Y Table:

X-Y table is the most important part of the AJM over which the workpiece has to be kept and machined. The travel of X-Y table has been decided to be 400 x 350 mm.

The different components of the X-Y table are:

1. LM guideway (2 pairs-4 nos.)
2. Ball screw (2 nos.)
3. Support unit (2 fixed & 2 supported)
4. Nut bracket (2 nos.)
5. Couplings (2nos.)
6. Standard nuts and bolts.
7. Other components (to be manufactured in the lab).

The X-Y table consists of two parts: (a) Upper table, (b) Lower table. The upper table is responsible for x- movement and has a travel of 400 mm. The lower table has a travel of 350 mm and is responsible for the y- motion of the workpiece.

The different diagrams of the assembled views along with dimensions have been shown below.

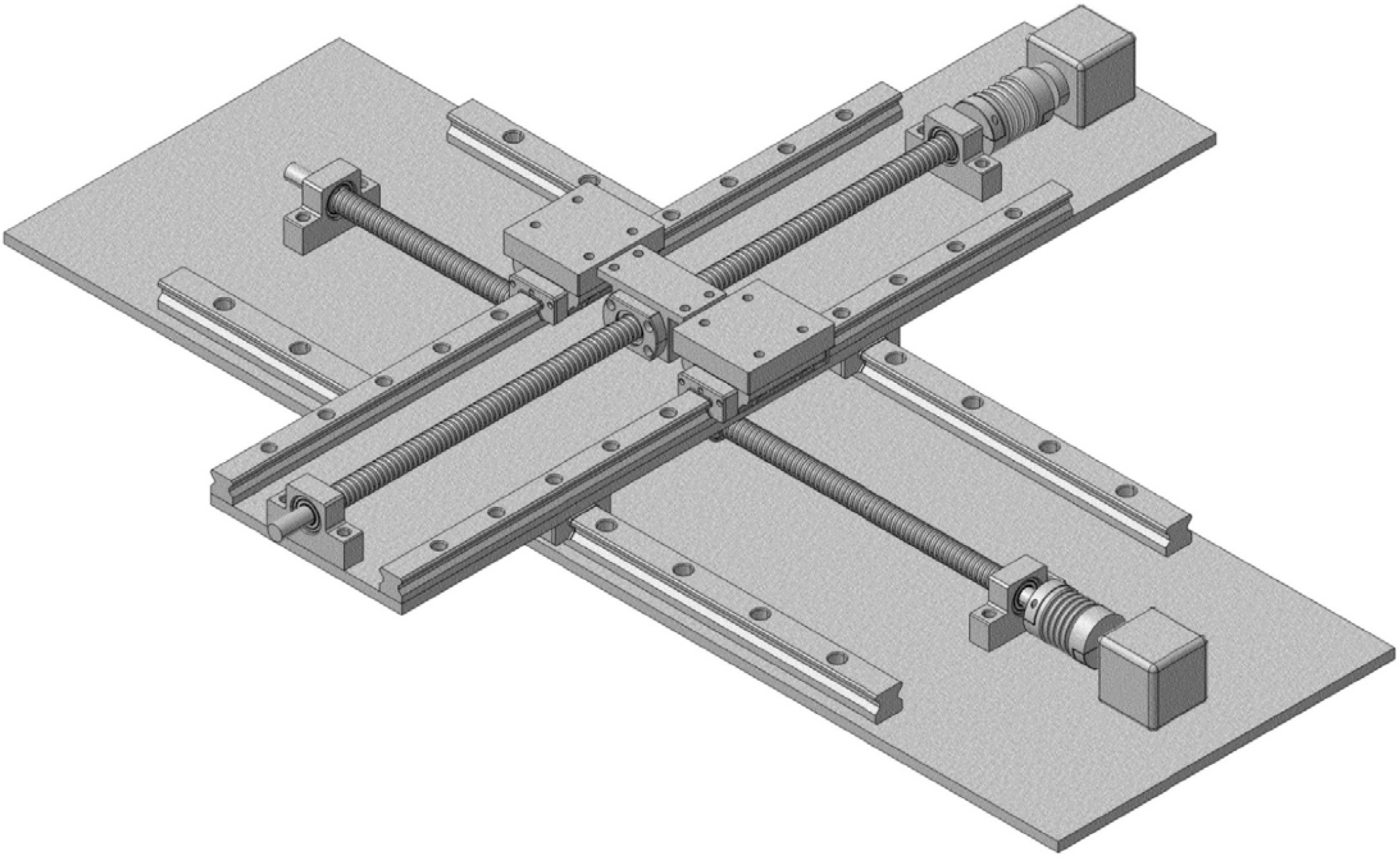

FIG-2: X-Y TABLE ASSEMBLY (ISOMETRIC VIEW)

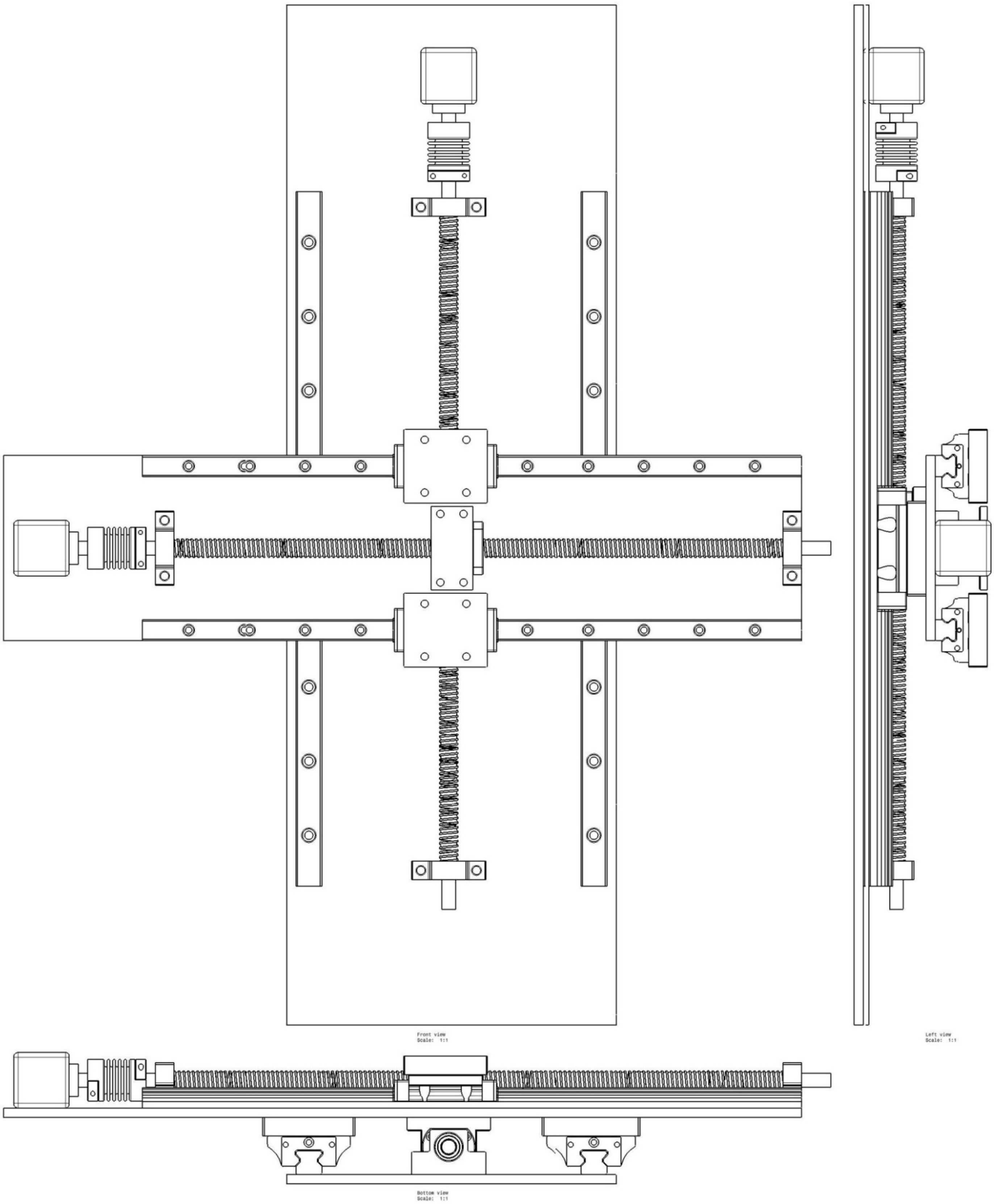

FIG-3: X-Y TABLE ASSEMBLY (2-D VIEWS)

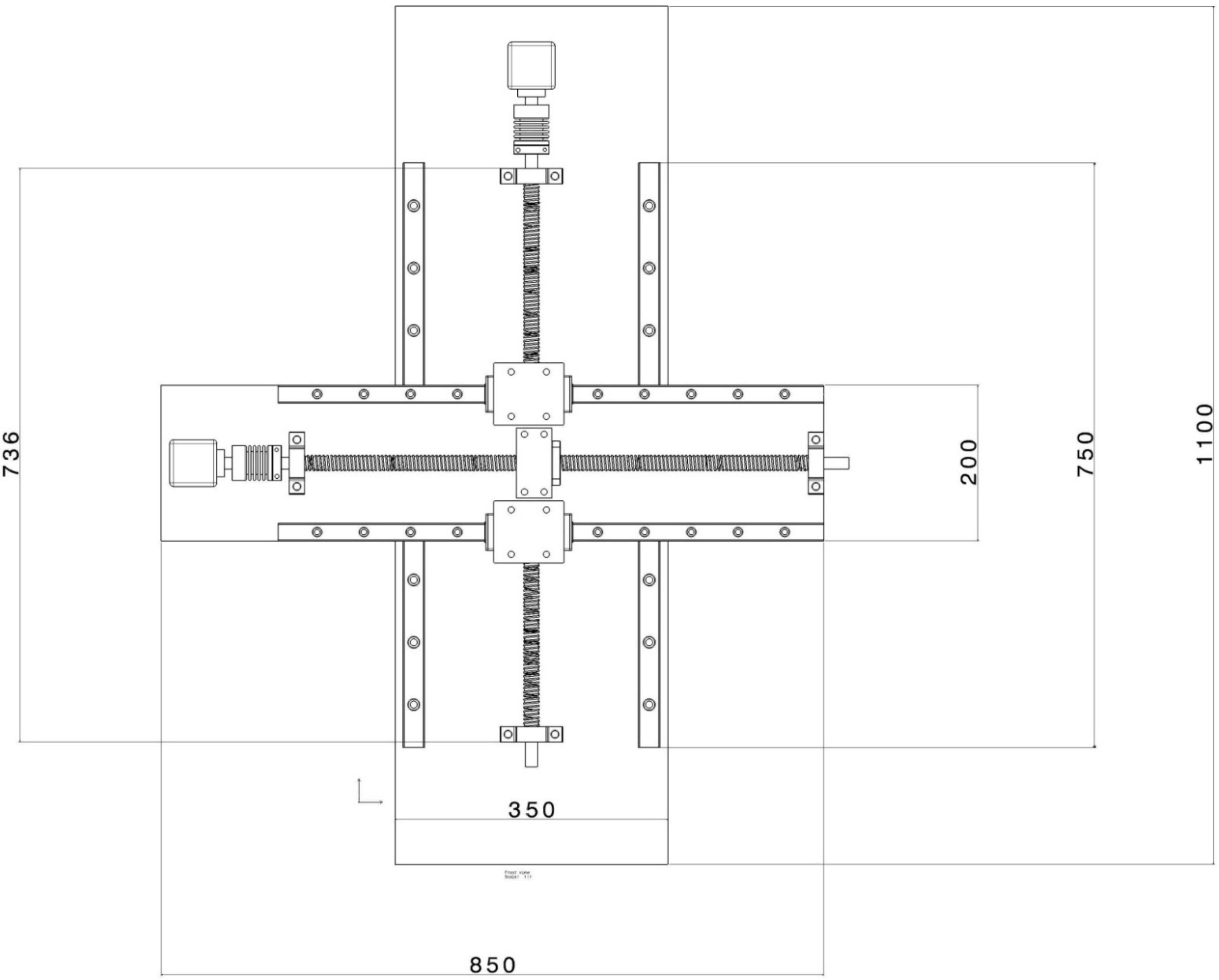

FIG-4: X-Y TABLE (TOP VIEW)

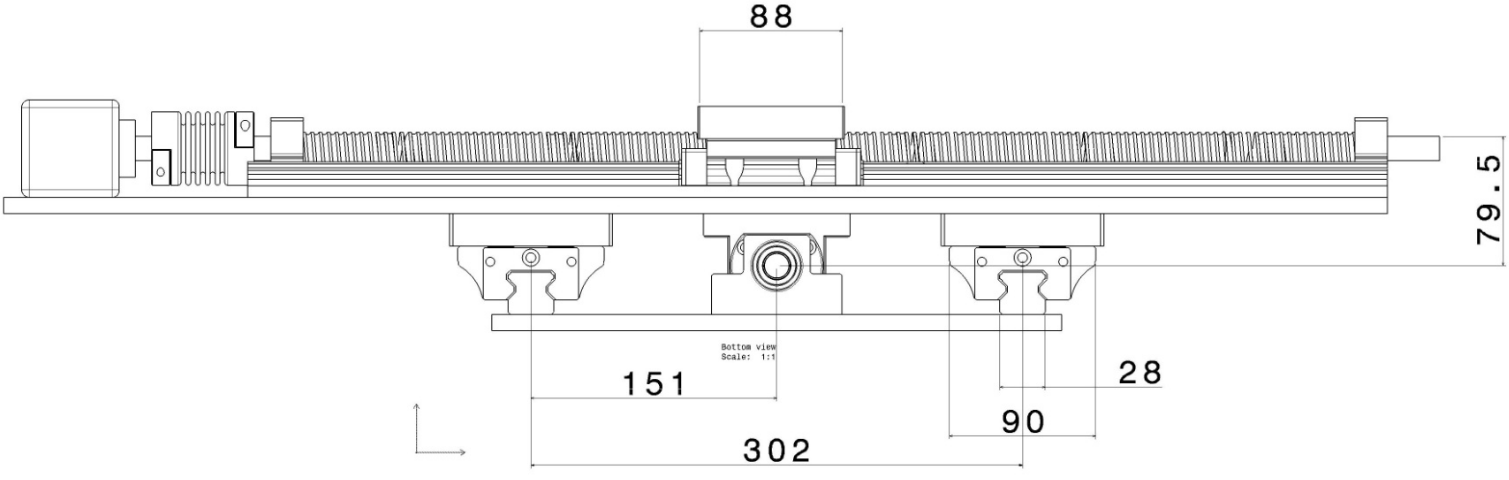

FIG-5: X-Y TABLE (SIDE VIEW)

3.1.2 Ball Screw:

Ball screw is similar to lead screw superficially but the friction is greatly reduced in case of ball screws by inserting recirculating balls in-between the screw thread and the nut. The thread profile is made circular and the nut thread has got a reverse shape which forms a spiral cavity inside which the balls move when the nut is rotated. Once the balls reach the end of the nut they are again recirculated by means of a return pipe. Ball screws can preloaded or non-preloaded. The accuracy increases in case of preloaded type of ball screw as two sets of balls are pressed toward each other thereby making the radial clearance close to zero.

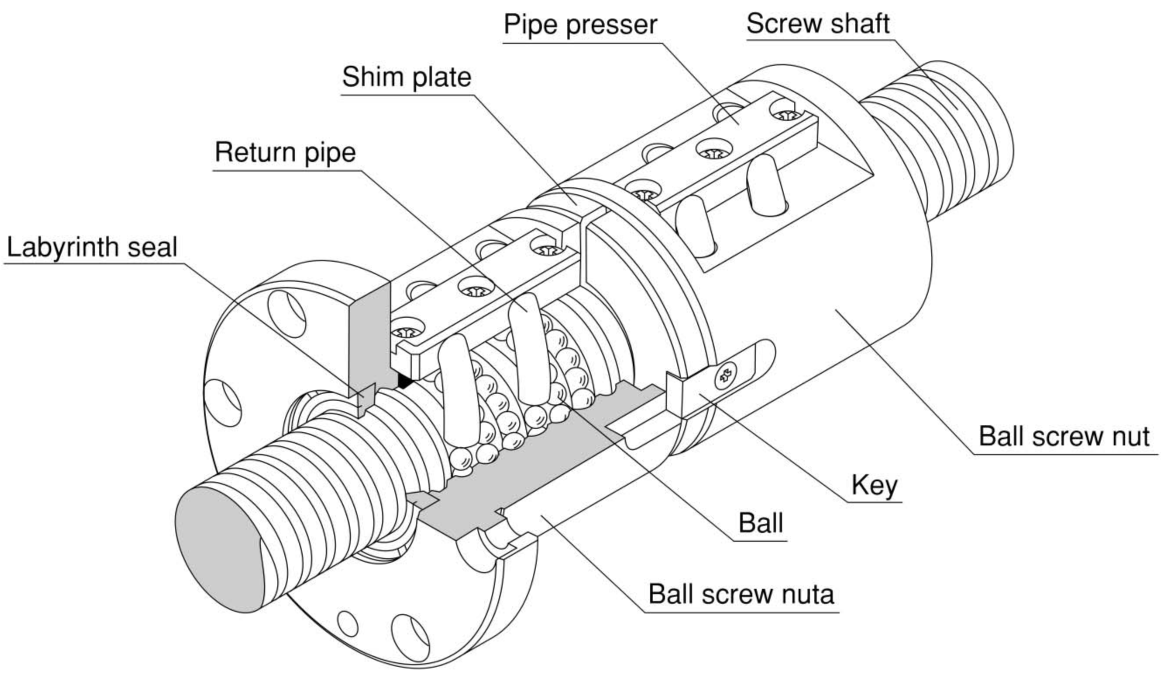

FIG-6: RECIRCULATING BALL SCREW

Screw length calculation:-

Travel of X-Y table has been decided to be 400 x 350 mm.

So screw of x- axis ball screw:

= 400mm	+	200mm	+	100mm
(Travel)		(Upper table breadth)		(Allowance for bellows cover)

= 700mm.

Screw length y-axis ball screw:

= 350mm	+	200mm	+	100mm
(Travel)		(Upper arrangement)		(Bellows cover allowance)

= 650mm.

Commercial Ball screws are available from companies like (1) THK, (2) Grampus Impex Ltd., (3) Precision Bearing House, and (4) ABBA etc.

The specifications by companies that satisfy our requirement are:

BNF-2005 5 RR G2 850L 700 C7 (by THK Company)

BNF → model no.

20 → screw shaft diameter

05 → lead

RR → labyrinth seal attached

G2 → axial clearance grade

850L → overall shaft length (in mm)

700 → screw length

C7 → accuracy symbol

SFI-2005 C7 800 650 P0

SFI	→	model no. (Single nut)
20	→	screw shaft diameter
05	→	lead
C7	→	accuracy grade
800	→	total length
650	→	screw length
P0	→	precision level

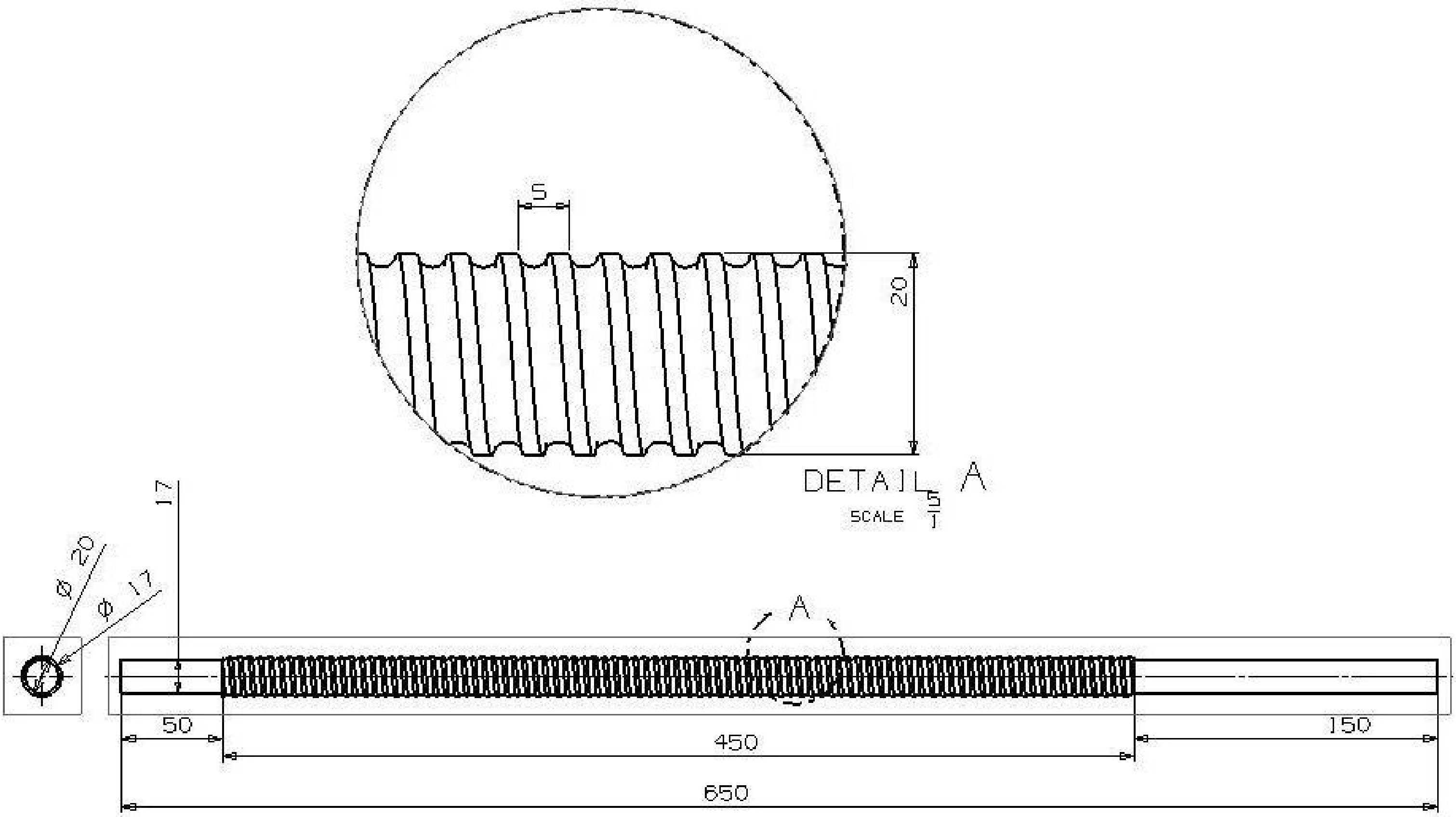

FIG-7: SCREW THREAD

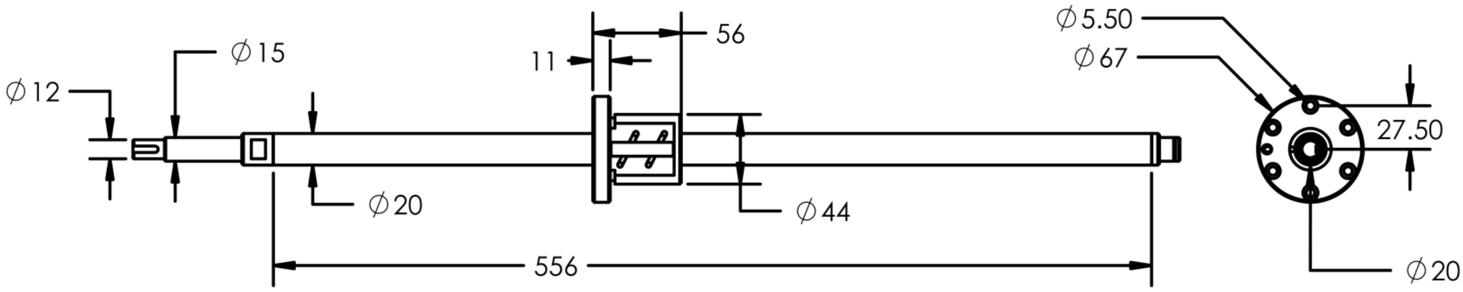

FIG-8: BALL SCREW ASSEMBLY (SHOWING DIMESIONS AND MACHINED ENDS)

3.1.3 LM-Guide or Linear Motion Guide Way:

LM-Guide as the name suggests is used for highly precise linear motion. It can sustain high loads in any direction and hence can be mounted in any direction. The assembly contains a rail which guides a block on it. Inside the block, ball or roller are present which drastically reduces the frictional losses. So LM-Guide is preferred in both industries and robotics to achieve specific functions.

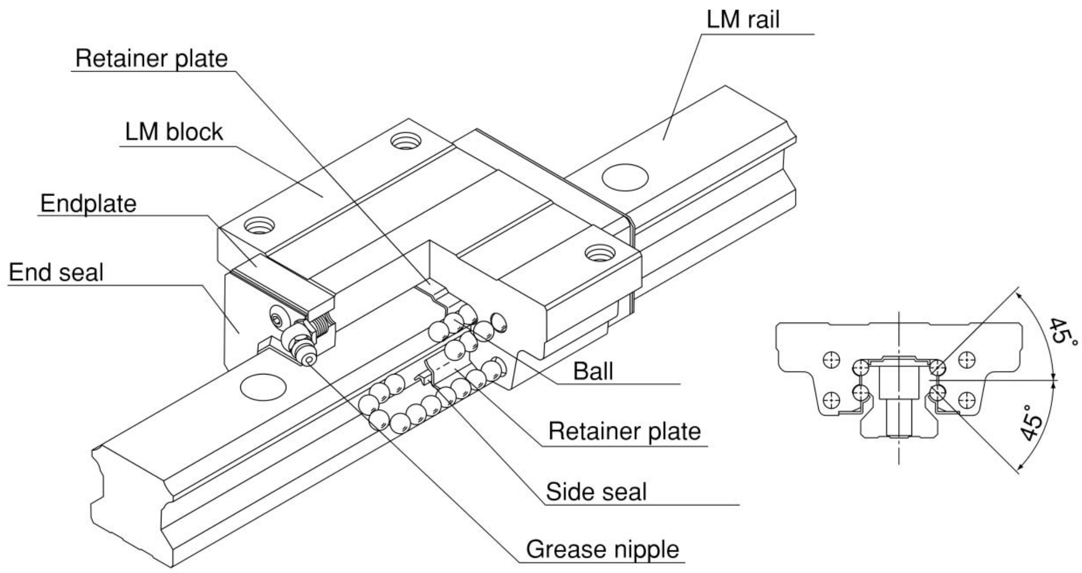

FIG-9: LM GUIDE ASSEMBLY

Structure and Features:

Balls roll in four rows of raceways precision-ground on an LM rail and an LM block, and end-plates incorporated in the LM block allow the balls to circulate. Since retainer plates hold the balls, they do not fall off even if the LM rail is pulled out (except models HSR 8, 10 and 12). Each row of balls is placed at a contact angle of 45°so that the rated loads applied to the LM block are uniform in the four directions (radial, reverse-radial and lateral directions), enabling the LM Guide to be used in all orientations. In addition, the LM block can receive a well-balanced preload, increasing the rigidity in the four directions while maintaining a constant, low friction coefficient. With the low sectional height and the high rigidity design of the LM block, this model achieves highly accurate and stable linear motion.

4-way equal load

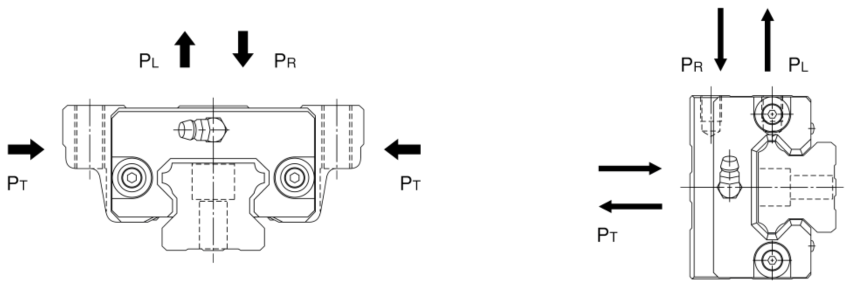

FIG-10: LOAD ON LM BLOCK

Each row of balls is placed at a contact angle of 45°so that the rated loads applied to the LM block are uniform in the four directions (radial, reverse-radial and lateral directions), enabling the LM Guide to be used in all orientations and in extensive applications

High-rigidity type

Since balls are arranged in four rows in a well-balanced manner, a large preload can be applied and the rigidity in four directions can easily be increased

High durability

Even under a preload or biased load, differential slip of balls does not occur. As a result, smooth motion, high wear resistance, and long-term maintenance of accuracy are achieved.

Rated Loads in All Directions

Model HSR is capable of receiving loads in all four directions: radial, reverse-radial and lateral directions. The basic load ratings are uniform in the four directions (radial, reverse-radial and lateral directions), and their actual values are provided in the dimensional table for HSR.

Equivalent Load

When the LM block of model HSR receives loads in the reverse-radial and lateral directions simultaneously, the equivalent load is obtained from the equation below

PE = PR（PL） + PT

Where

PE ：Equivalent load (N)

・Radial direction

・Reverse-radial direction

・Lateral direction

PR ：Radial load (N)

PL	: Reverse-radial load	(N)
PT	: Lateral load	(N)

Advantage of LM Guide

1. Smooth movement with no clearance.
2. High running precision with ease.
3. High rigidity in all direction.
4. High permissible load rating.
5. High long term precision.
6. High speed operation.

These combine to give rise

1. Low total cost.
2. High precision in machines incorporating the LM guide.
3. High productivity in the same.
4. Substantial energy saving.
5. High efficiency in machine design.
6. Simple maintenance.

Rail length calculation:

Length of rail should be approximately 50 mm larger than that of corresponding ball screw.

Hence in X- axis: rail length = 750 mm.

Y- axis: rail length = 700 mm.

LM Guides are commercially available from companies like (1) THK, (2) Grampus Impex Ltd., (3) Precision Bearing House, and (4) ABBA etc.

The specification by companies that satisfy our requirement is:

HSR 30 R2 SS C5 700L H II

HSR	→	model no.
30R	→	size specification
2	→	2 blocks per rail
SS	→	end seal + side seal
C5	→	radial clearance
700L	→	standard length
H	→	accuracy grade
II	→	2 rails

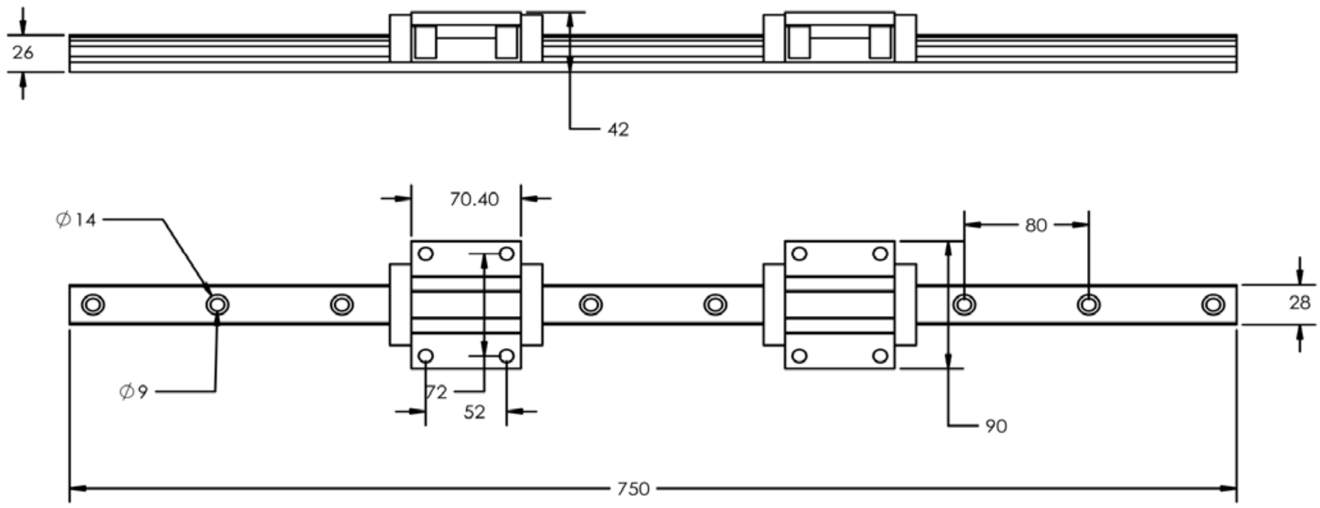

FIG-11: DIMENSIONS OF LM GUIDE

3.1.4 Support Unit:

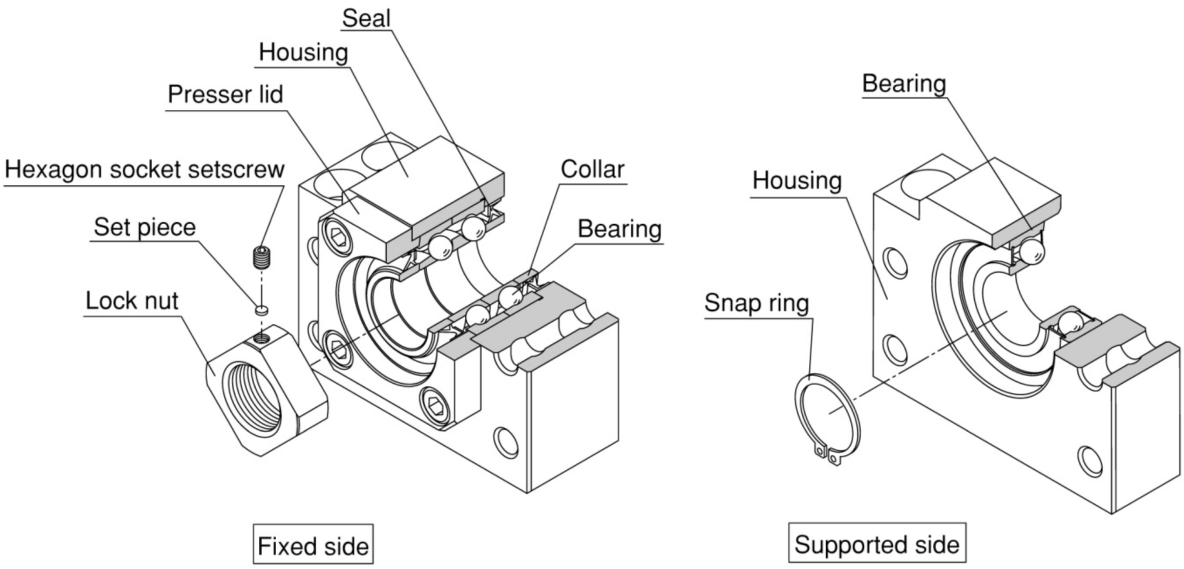

FIG-12: SUPPORT UNIT

Support units are required for supporting the ballscrew ends. These are special kind of bearings which gives longer service life and better performance. They are of 2 types,

1. Fixed end support unit,
2. Supported end support unit.

In fixed end the support unit acts like a thrust bearing and takes all the thrust given by the work load. In the supported end the support unit just acts like simple bearing.

Various types of supported units are available commercially. They differ mainly in the manner they need to be fixed or bolted to a wall or a metal plate. Accordingly the fixing holes are provided on the face or sides of the support unit.

Support units available commercially by THK are type EK for fixed side and FK for supported side.

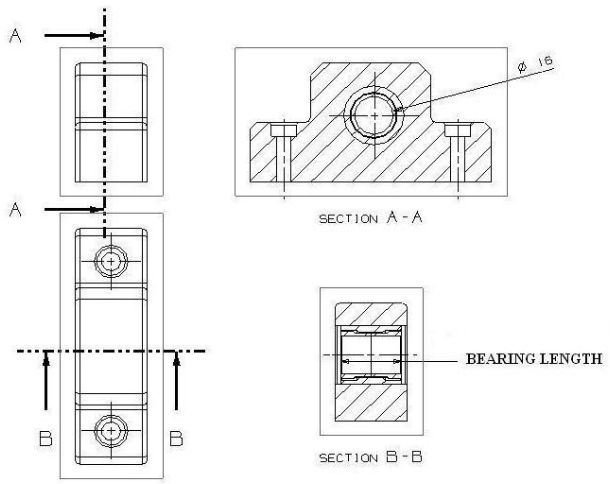

FIG-13: SUPPORT UNIT (DESIGN EF)

3.1.5 Nut Bracket:

Nut bracket is used to bolt the ball screw nut with the work load platform. Following diagram shows a nut bracket along with a ball screw nut.

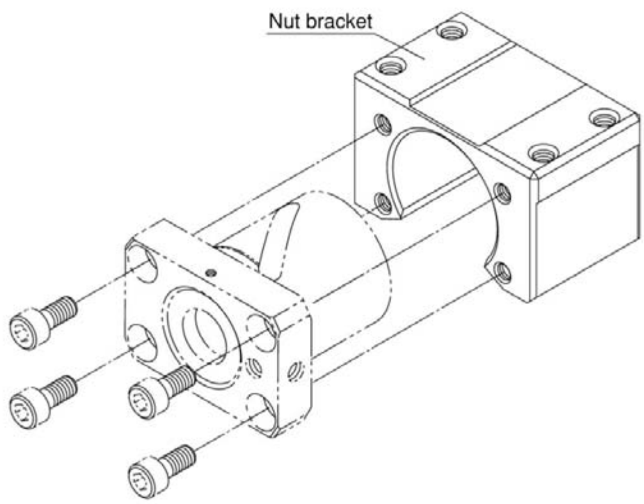

FIG-14: NUT BTACKET

3.2 Z-Axis Assembly or Vertical Motion Module:

Vertical motion module is required for adjusting the nozzle height or stand off distance from the workpiece. When different operations are to be carried out, the set up time between operations can be eliminated if the nozzle tip is raised to a height more than 5 cm. At this distance the abrasive jet has negligible erosion effect on the workpiece. Hence the total Z- motion has been decided to be 100mm.

The different components of the Vertical motion module are:

1. LM guide way (1 no.)
2. Ball screw (1 no.)
3. Support unit (1 fixed & 1 supported)
4. Couplings (1 no.)
5. Nozzle (1 no.)
6. Standard nuts and bolts.
7. Other components (to be manufactured in the lab).

The assembly view is shown in the next page.

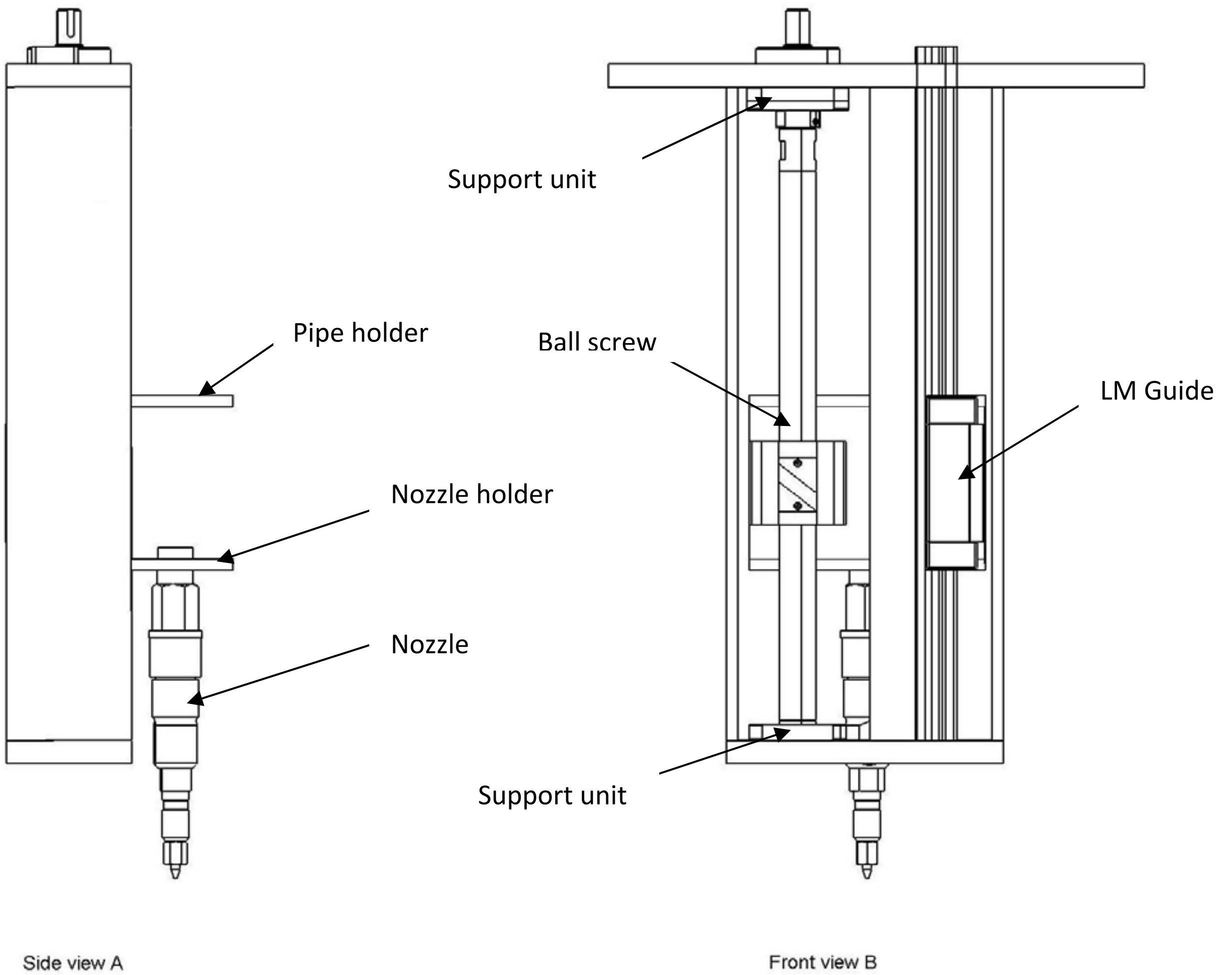

FIG-15: VERTICAL MOTION MODULE

3.2.1 LM guide way:

The LM Guide selected is of the type HSR-YR. The special feature of HSR-YR is that the tapped holes are present on the side of the LM Block and hence they can be attached to the load component from the side.

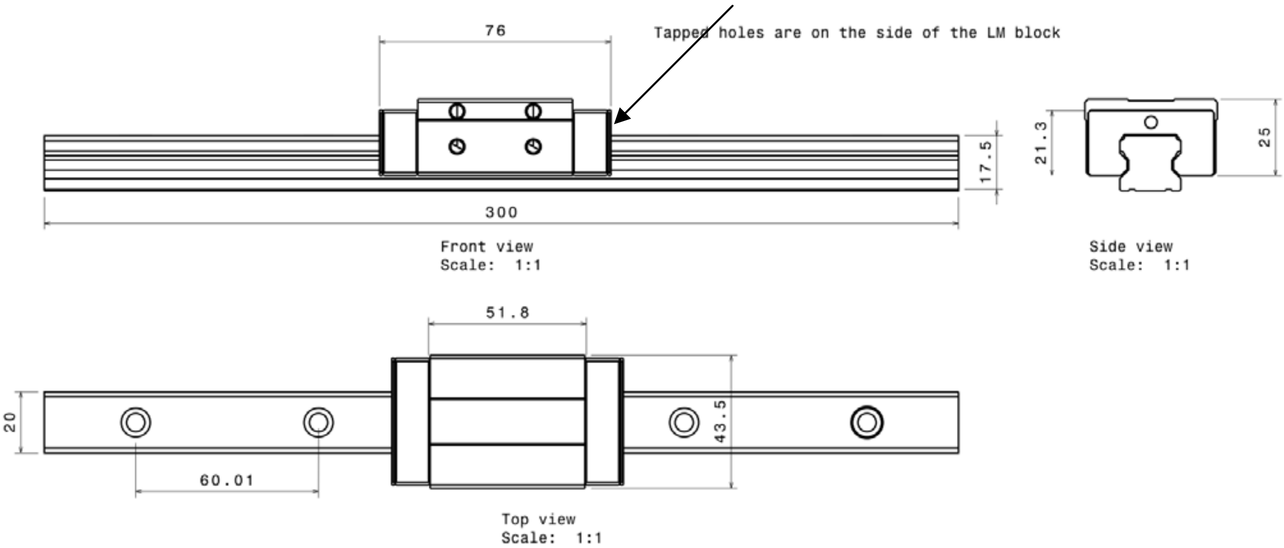

FIG-16: LM Guide (type HSR-YR)

3.2.2 Ball Screw & Support Unit

The ball screw selected for the Z- axis assembly is of the type BNT. The support units are EK and FK for fixed end and supported end respectively. The smaller space in the Z-assembly doesn't allow for the use of a nut bracket for the ball screw nut. So the BNT type ball screw has been selected from THK catalogue as it has tapped holes on the nut itself which can be screwed to the load directly.

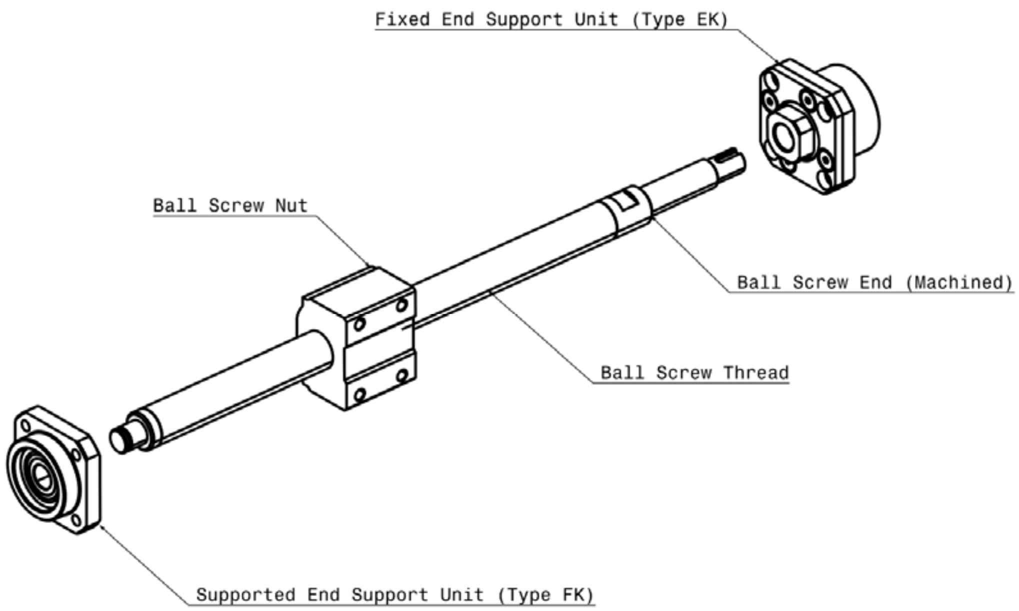

FIG-17: BALL SCREW AND SUPPORT UNIT

3.2.3 Nozzle:

The abrasive particles are directed into the work surface at high velocity through nozzles. Therefore, the material of the nozzle is subjected to great degree of abrasion wear and hence these are made of hard materials such as tungsten carbide or synthetic sapphire. Tungsten carbide nozzles are used for circular cross-sections in the range of 0.12-0.8 mm diameter, for rectangular sections of size 0.08 x 0.05 to 0.18 x 3.8 mm and for square sections of size upto 0.7 mm. Sapphire nozzles are made only for circular cross-sections. The size varies from 0.2 to 0.7 mm diameter. Nozzles are made with an external taper to minimize secondary effects due to ricocheting of abrasive particles. Nozzles made of tungsten carbide have an average life of 12 to 30 hours while nozzles of sapphire last for about 300 hour of operation when used with 27 µm abrasive powder.

The rate of material removal and the size of machined area are influenced by the distance of the nozzle from the workpiece. The abrasive particles from the nozzle follow a parallel path only for a short distance and then the jet flares resulting in the oversizing of the hole. It is observed that the jet stream is initially a cylinder for about 1.6 mm and then it flares into a cone of 7° included angle. The material removal rate initial increases with increase in the distance of the nozzle from the workpiece because of the acceleration of particles leaving nozzle. This increase is maximum up to a distance about 8 mm and then it steadily drops off because of increase in machining area for the same amount of abrasive and decrease in velocity of abrasive stream due to drag.

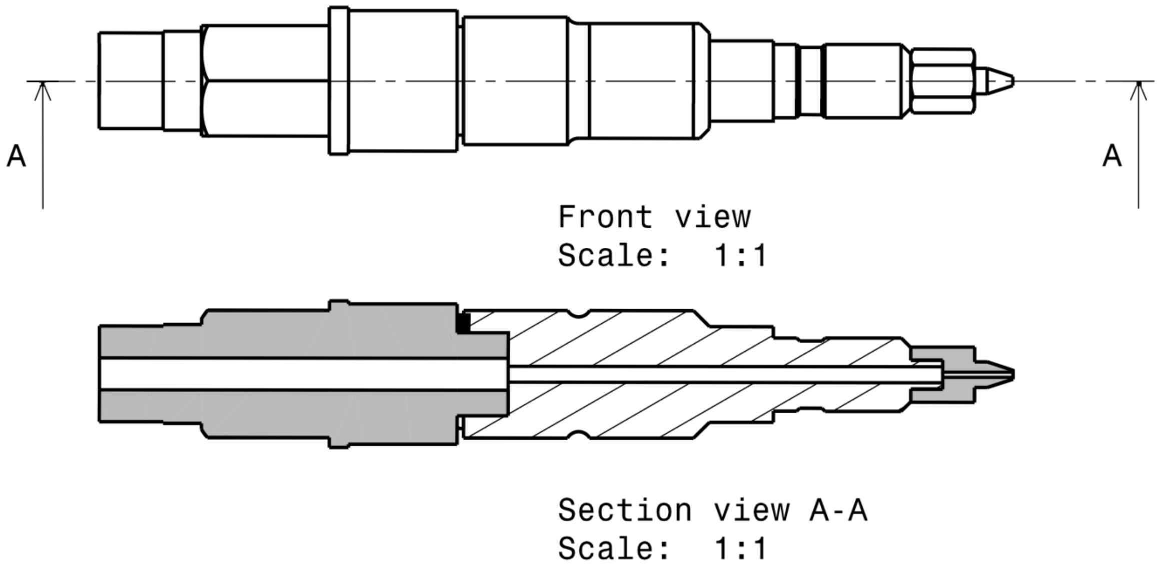

FIG-18: NOZZLE

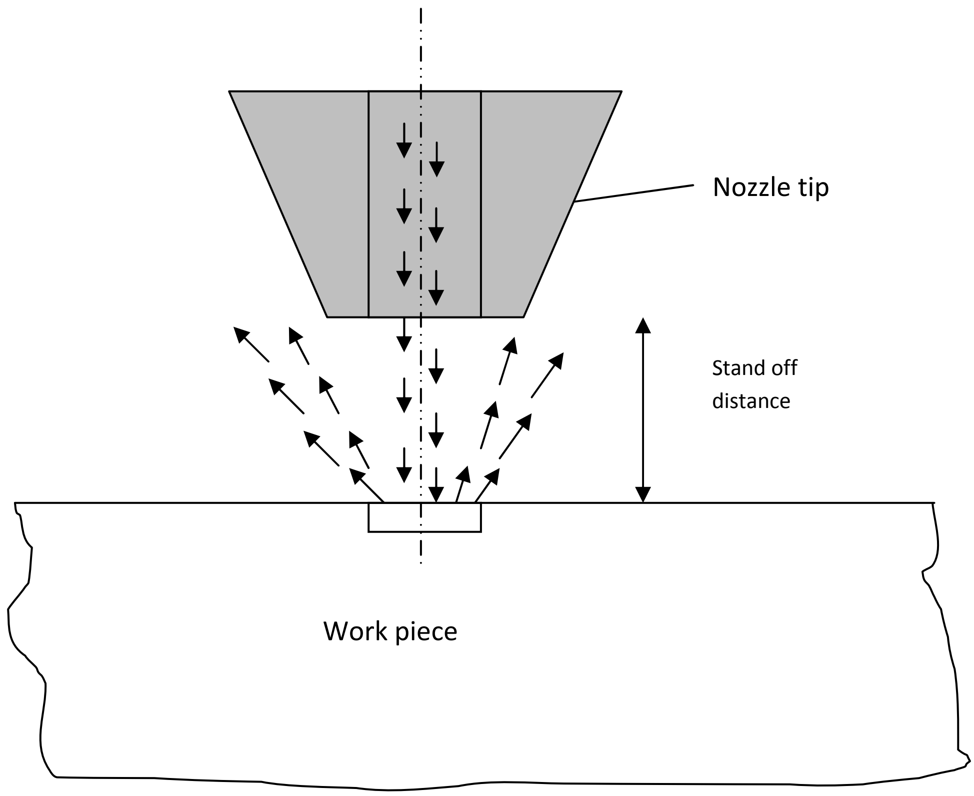

FIG-19: Abrasive action of particles

3.2.4 Limitations of Abrasive Jet nozzles:

Despite their simple design, abrasive jet nozzles can be troublesome at times. There are many designs, but they share the same problems:

1. Short life of an expensive wear part
2. Occasional plugging of mixing tube: Usually caused by dirt or large particles in abrasive.
3. Wear, misalignment, and damage to the jewel.

3.3 TOTAL ASSEMBLY

The assembly drawing of the abrasive jet machine can be represented as follows. It can be noted that the components like air compressor, vibrator, dehumidifier, bellows cover and piping have not been shown in the drawing

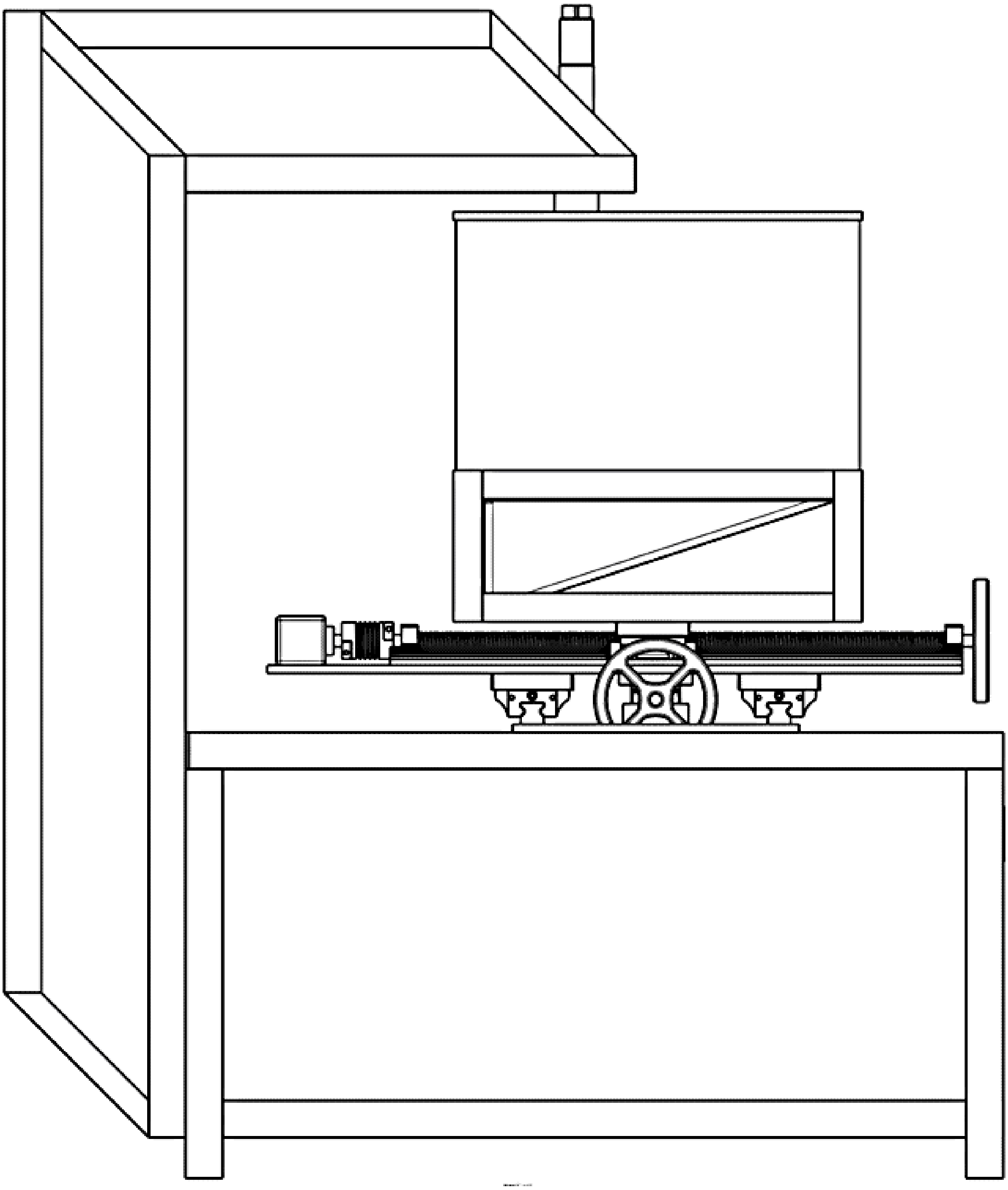

FIG-20: SIDE VIEW OF WHOLE ASSEMBLY

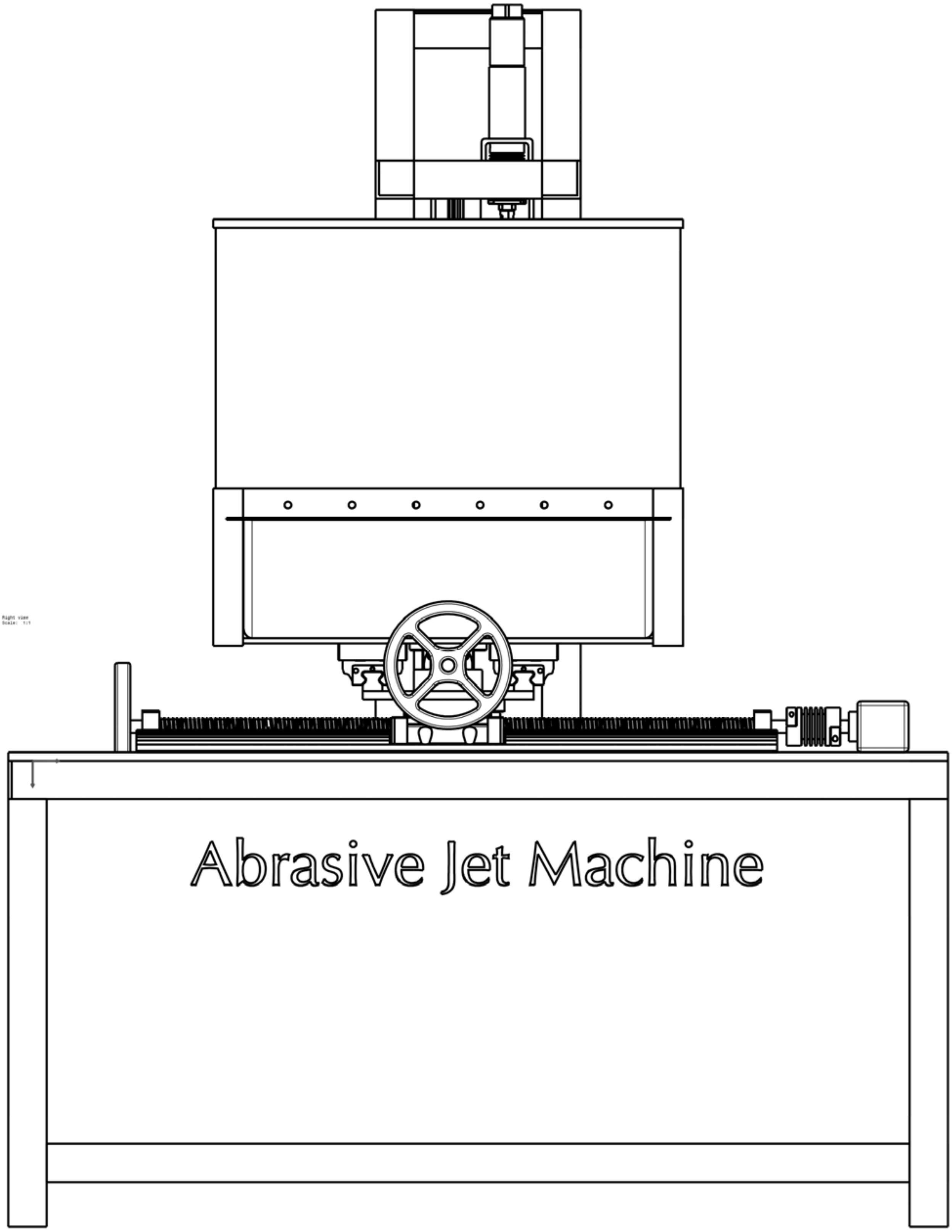

FIG-21: AJM FRONT VIEW

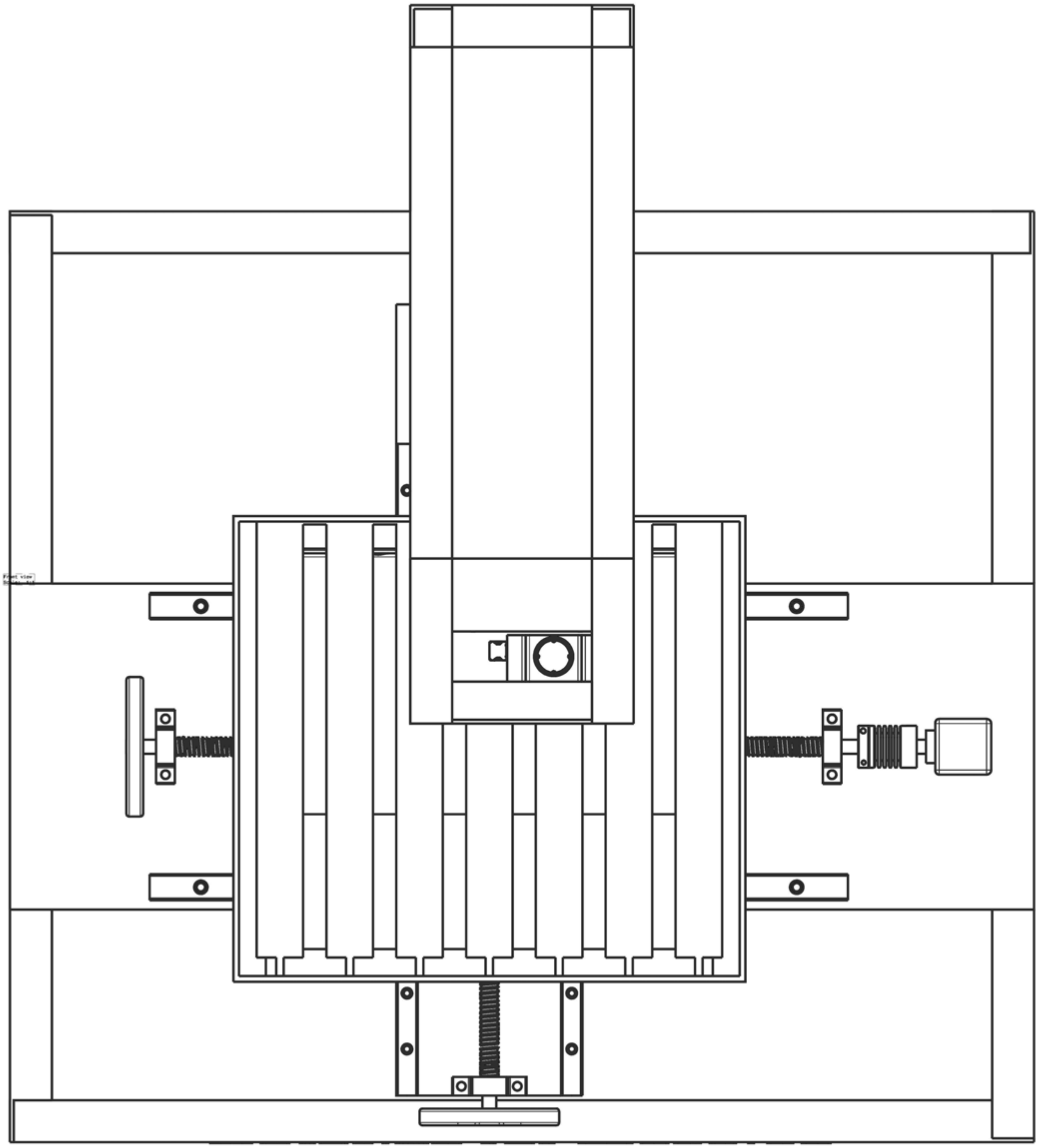

FIG-22: AJM TOP VIEW

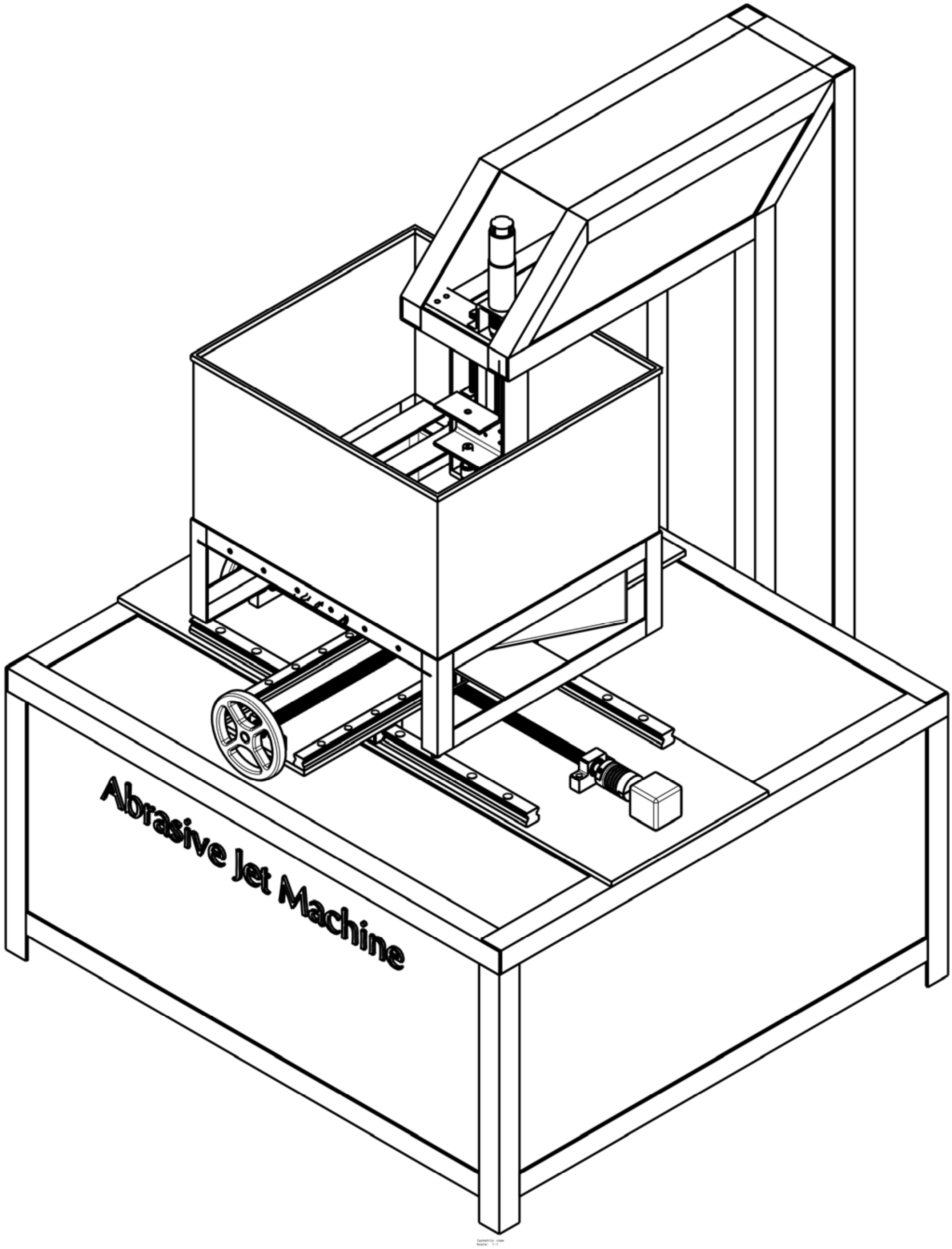

FIG-23: AJM ISOMETRIC VIEW

3.4 Other Components

3.4.1 FRL Unit (Dehumidifier):

The FRL Unit (Air Filter Regulator Lubricator unit) which is otherwise called the moisture separator or dehumidifier is required for separating the moisture from air. Atmospheric air always contains some water vapour in it. As the air with high velocity is blown from the nozzle there is an abrupt rise in pressure which converts water vapour into moisture. The moisture makes the abrasive particles to agglomerate and this clogs the outlet of the Nozzle. To avoid this clogging moisture separator should be used before abrasive particles are mixed with compressed air. Different FRL Units are available commercially.

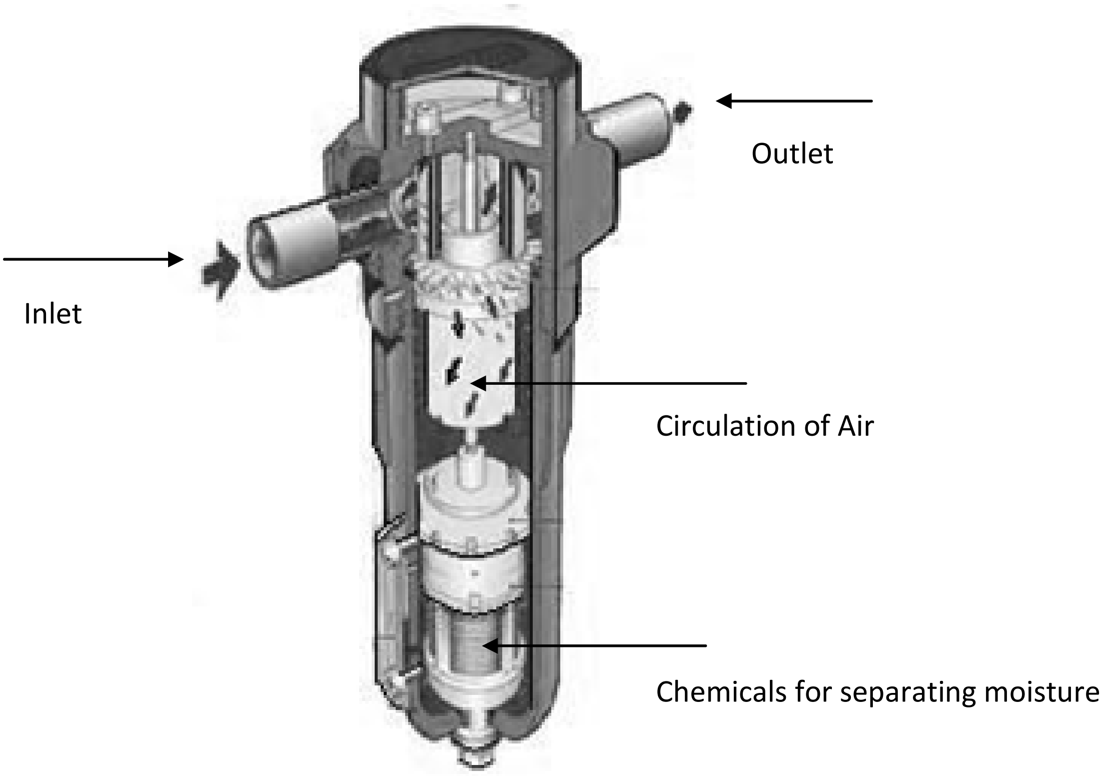

FIG-24: FRL Unit

3.4.2 The Vibrating Unit:

Vibrating Unit is used for mixing the air with the abrasive particles (Al_2O_3). The Abrasive particles are stored in a container through which air is flown. The particles are agitated by means of a cam and motor arrangement. The rotation of cam results in vibration in the abrasive container. The flow rate of abrasive materials can be controlled by manipulating the rotational speed of the motor. The abrasive container will have one inlet and one outlet for air passage and will be vertically suspended from a hinged joint.

So the Vibrating Unit consists of following parts –

1. Motor (Induction type)
2. Cam
3. Abrasive container

Abrasive Container:

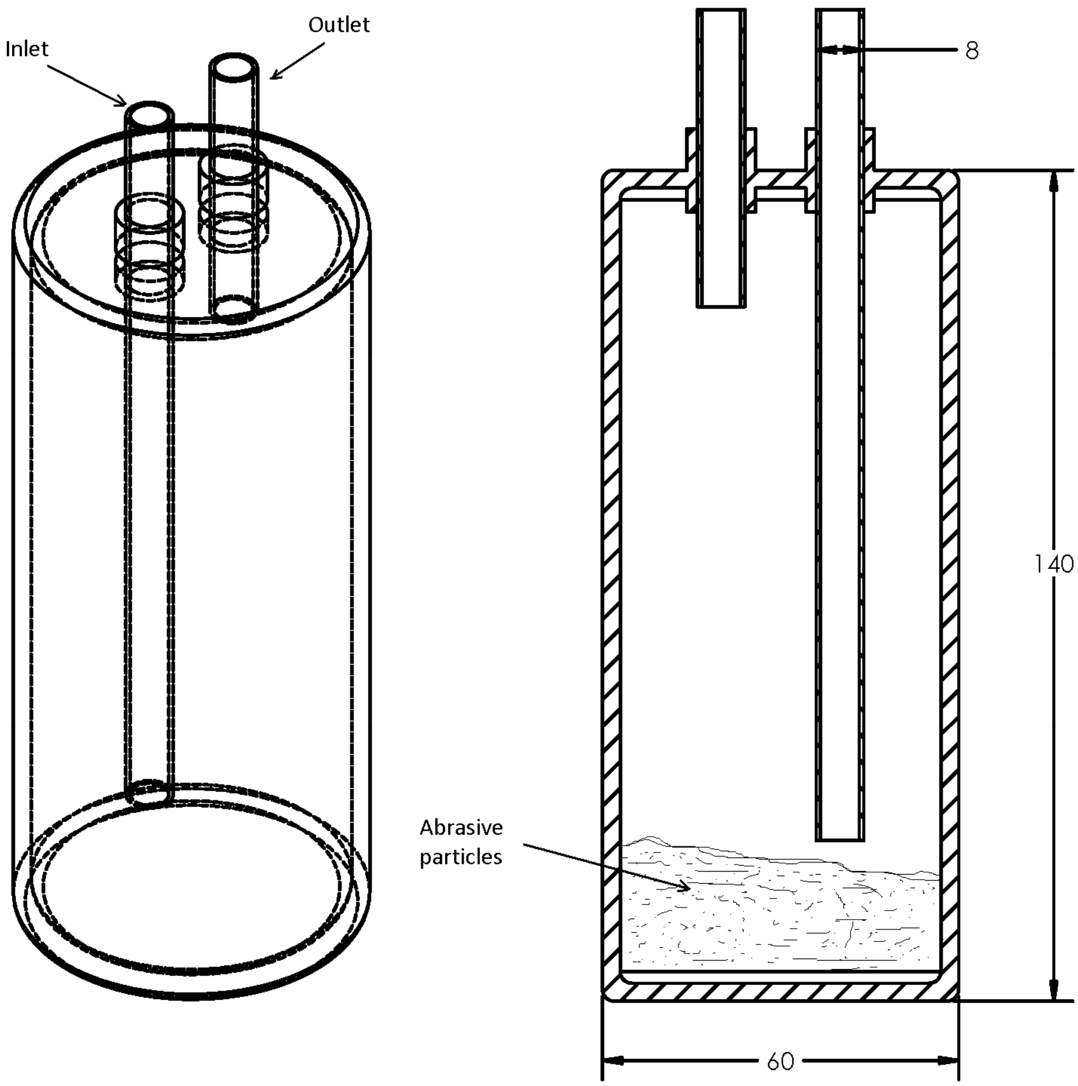

FIG – 25: The Abrasive Container.

Cam:

Cam is fixed with shaft of the induction motor. The profile of the cam is taken to be a circular one. The distance between two centers as shown in fig-26 is 3mm. When the motor rotates; it makes the container to vibrate. Width of cam is 25mm.

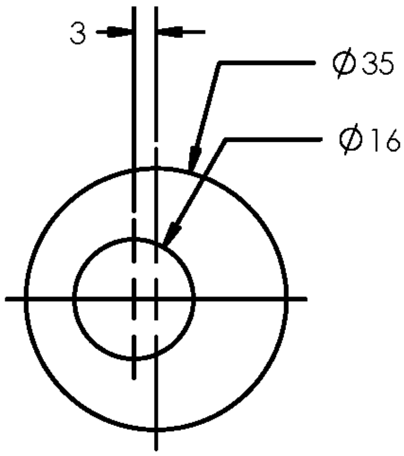

FIG-26: Cam

3.3.5 Approximate Cost Estimation:

TABLE: 2 (Cost estimation)

SL NO.	NAME OF THE ITEM	COST PER SINGLE PIECE	NO. OF ITEMS REQUIRED	TOTAL COST FOR THE ITEM
1	Recirculating ball screw X- axis Y- axis Z- axis	 Rs. 10,000.00 Rs. 7,000.00 Rs. 5,000.00	 1 1 1	Rs. 22,00.00
2	Linear Motion guide ways X- axis Y- axis Z- axis	 Rs. 17,000.00 Rs. 14,000.00 Rs. 6,000.00	 1 pair 1 pair 1	Rs. 37,000.00
3	Support Unit X- axis ball screw Y- axis ball screw Z- axis ball screw	 Rs. 3,000.00 Rs. 2,500.00 Rs. 2,500.00	 2 2 2	Rs.16,000.00
4	FRL Unit	Rs. 2,500.00	1	Rs. 2500.00
5	Vice	Rs. 2,000.00		Rs. 2,000.00
6	Angles	Rs. 1000.00		Rs. 1000.00
7	Other accessories			Rs. 7,500.00
	TOTAL			Rs. 88,000.00

PART FOUR

FABRICATION AND ASEMBLING

4.1 Nozzle:

A standard MS cylindrical rod was cut into required length by power hack-saw. The external diameter was then brought to 16mm by turning it in lathe and then the tip was made by tapering one end by the same lathe. A blind hole of approximate depth 20mm was made on the planner face of the rod by means of a 12mm drill bit in a drilling machine. The end of the blind hole forms a shape of 118 degree taper because of the tool tip angle. Internal threading was made by 12mm tap. Then the tip of the nozzle was made by drilling it by a 0.74mm diameter drill bit to get approximate diameter of 1mm.

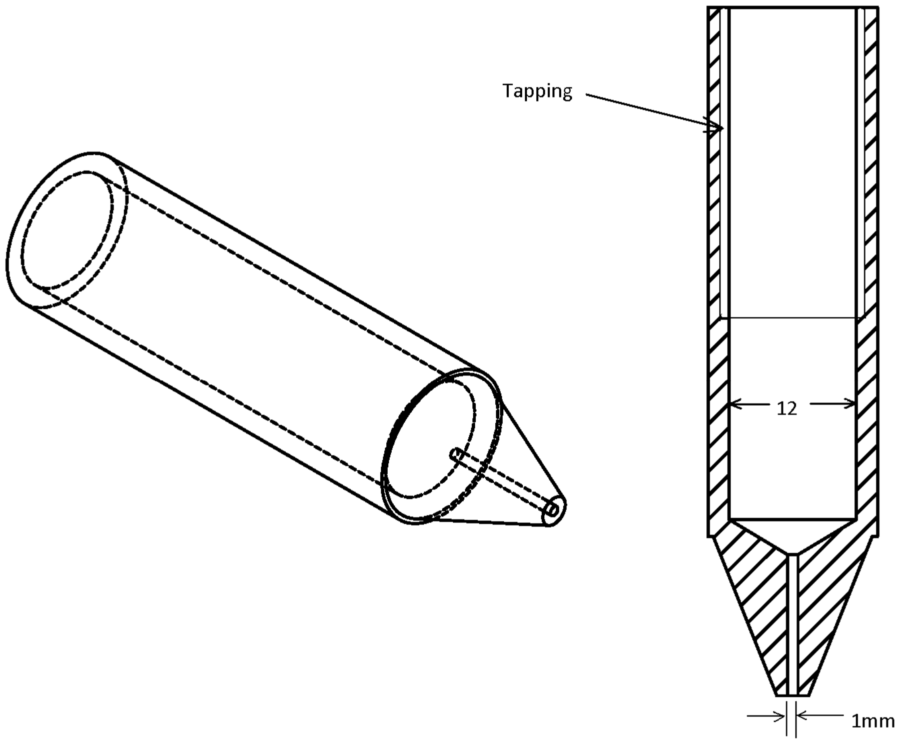

FIG- 27: Nozzle

4.2 CAM:

Mild steel of diameter 40mm was taken as raw material for this operation. At first turning was done in a lathe to bring down the diameter to 35mm. Then the required width (25mm) was cut by power hack-saw and both the cut faces were machined in a milling machine. Then a through hole was made by a 16mm drill bit in a drilling machine. The center offset was taken to be 3mm.

4.3 ABRASIVE CONTAINER:

The abrasive container was made out of a hollow cylinder. Two iron plates were welded on both ends of the container. On the top plate two holes were drilled and iron pipes were fitted with these holes. The inlet iron pipe is longer so as to make more agitation of the abrasive particles. The outlet pipe is shorter. Both the pipes are clamped with nylon pipes which carries air through them. After removal of moisture by the FRL unit the compressed air goes to abrasive container through inlet, mixes with abrasive particle and then the air with abrasive particles moves through the nozzle to perform the machining action.

4.5 THE VIBRATOR ASSEMBLY:

The angle section was welded with base plate by arc welding. A rod was welded with angle orienting it parallel with base plate. An induction motor was placed on the base plate by tighten with nut bolt. Cam was fixed with motor shaft. Then abrasive container was connected to the rod by means of the holder. The container is free to rotate around the rod.

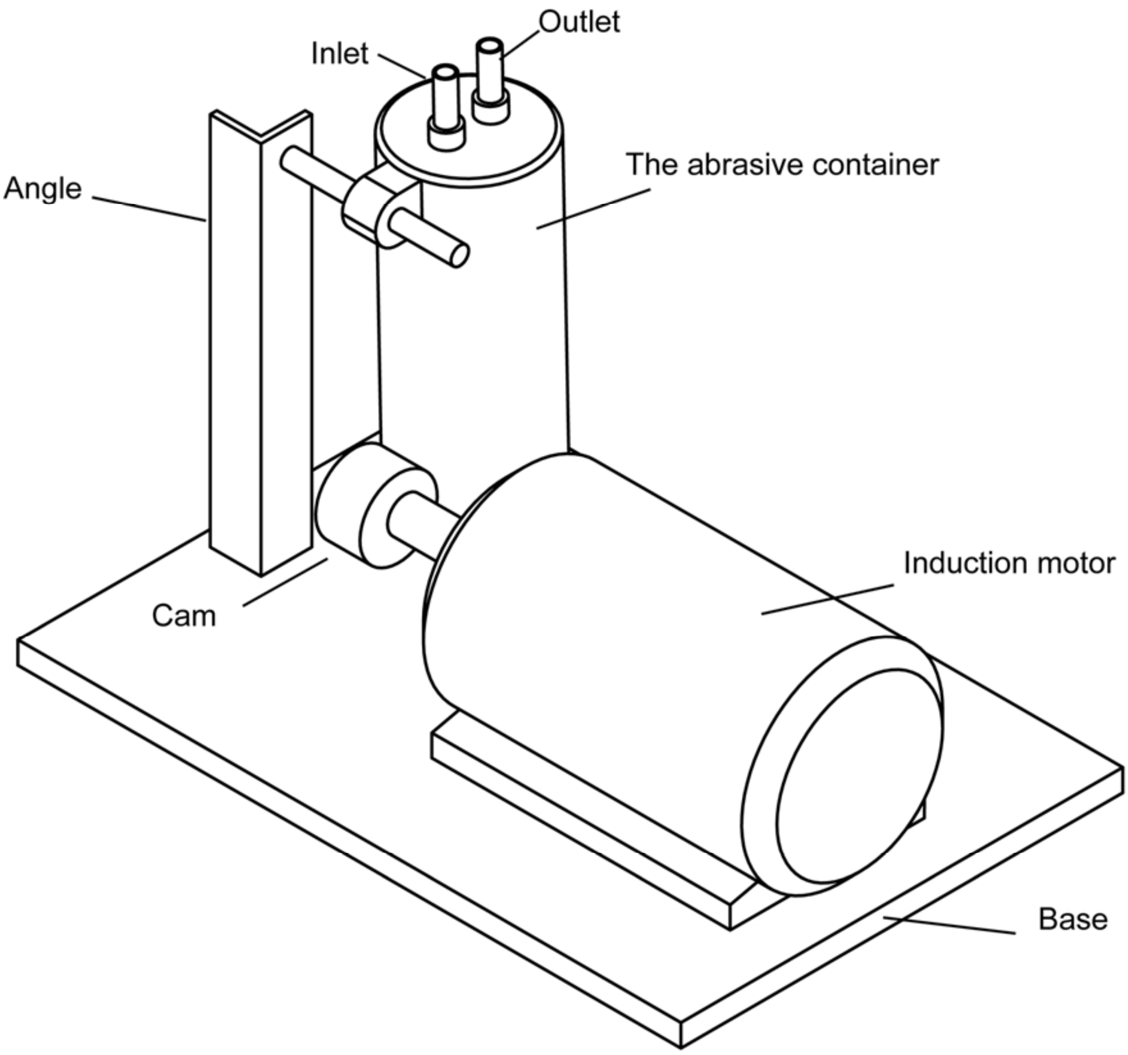

FIG- 28: The vibrator assembly

CONCLUSION

In this project a complete design of the Abrasive Jet Machine is given. The XYZ motion modules are designed taking in account of currently available components in the market. The designing and assembling of very large number of components was a tremendous task and was completed on time. However because of some parts couldn't be purchased the whole assembly was limited to drilling operation.

The project can go beyond its current position and capabilities by employing automation into it. This can be done by using stepper motors or DC servo motors interfaced with standard PCI controllers or standalone controllers. 2-D profiles can be converted into standard G-codes and M-codes and that can be sent to the machine to perform automated machining.

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